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Polimaster PM1401K-3 Test Report

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Executive Summary

Extensive testing, including measurements on large quantities of special nuclear material, were taken to assess the functionality of the Polimaster PM1401K-3 to other detectors used in the field. The Polimaster can detect alpha, beta, gamma, and neutron radiation. However, efficiency and accuracy has been sacrificed to accomplish this. Compared to the IdentiFINDER 2, SRM, and FH-40 alpha probe, the Polimaster underperforms in almost all categories regarding radiation detection. The Helium-3 neutron detector in the Polimaster, due to a larger volume, outperformed the IdentiFINDER 2 for neutron measurements. The alpha search mode showed higher efficiency than the FH-40 alpha probe, but uses a more complicated process. The user interface is relatively easy to navigate, clear, and comparable to other detectors. However, the detector has added complications when trying to detect alpha or beta radiation or save a spectrum.

Equipment Used

Polimaster PM1401K-3

SRM (LaBr variant)

ID R400 (LaBr variant)

FH-40 with alpha probe

Acronyms

CPS: Counts per second

CPM: Counts per minute

CsI: Cesium Iodide

DAF: Device assembly facility

DPS: Disintegrations per second

DPM: Disintegrations per minute

FWHM: Full width half maximum

HEU: Highly enriched uranium

ID: Inner diameter

LaBr: Lanthanum Bromide

NU: Natural uranium

OD: Outer diameter

SNM: Special nuclear material

WGPu: Weapons grade plutonium

Gamma Testing

The Polimaster PM1401K-3 was taken to the DAF to perform gamma testing with large (kilogram) quantities of SNM. Measurements were also taken with the SRM and ID R400 for comparison. The MicroDetective spectra are included to see the difference between scintillator spectra and HPGe spectra. A comparison between the Polimaster and MicroDetective would be unfair.

General Notes:

The Polimaster ranks identifications based on certainty (Certain, Uncertain, Very Uncertain). It consistently ranked the nuclide present as uncertain or very uncertain with several other nuclides ranked higher. For example, in the "Identify" mode, it had a hard time identifying Neptunium-237 on a bare neptunium sphere. For the short count time, it didn't identify ^{237}Np at all, and for the 5-min collection, it ranked ^{237}Np below 3 or 4 other isotopes that were not present at all. During SNM measurements, it consistently ranked medical or industrial isotopes not present as a higher certainty than the actual SNM. The low resolution of the CsI crystal would contribute significantly to this identification problem.

The user can set a time for "Identify" mode, but that time does not impact spectrum collection. For spectra collection, the only option is manual end collection only. There doesn't seem to be an option to view/save a spectrum if you use "Identify". Additionally, it does not show the identification in real time or upon completion of spectrum collection. There are several extra button pushes to get an identification and save a collected spectrum.

Measurement Comparison:

Figures 1-4 show spectra of a ^{237}Np item in order of increasing resolution. The lowest resolution is the Polimaster, then the SRM and ID R400, and a MicroDetective (HPGe). The SRM and ID R400 have comparable resolution being both LaBr crystals.

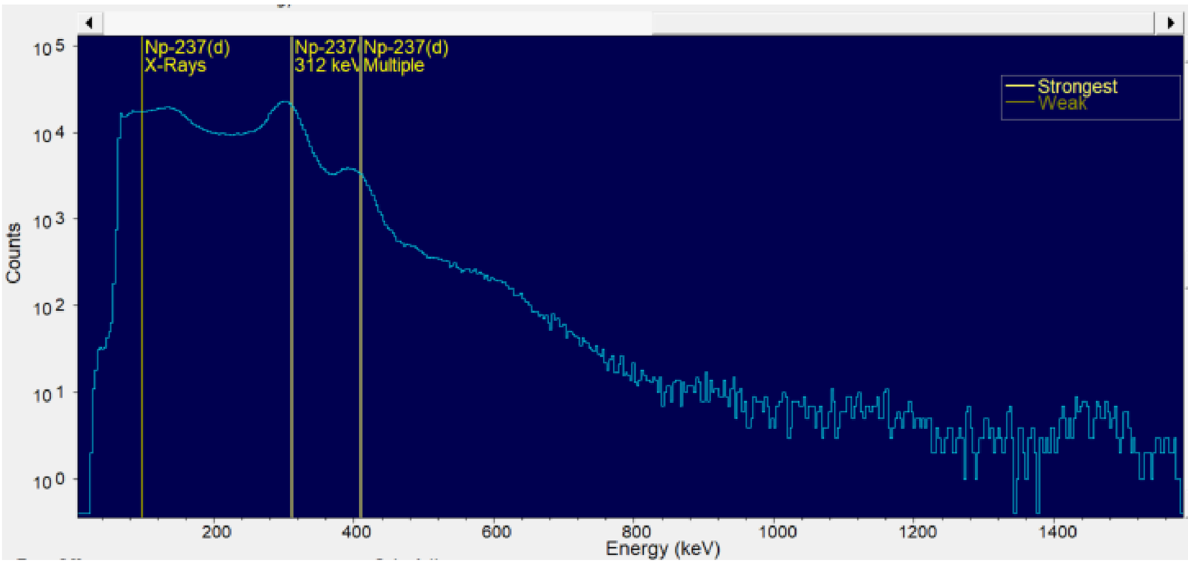

Figure 1. Polimaster spectrum of ^{237}Np item. The Polimaster identified ^{67}Ga, ^{75}Se, and ^{233}U ahead of ^{237}Np even though those isotopes were not present.

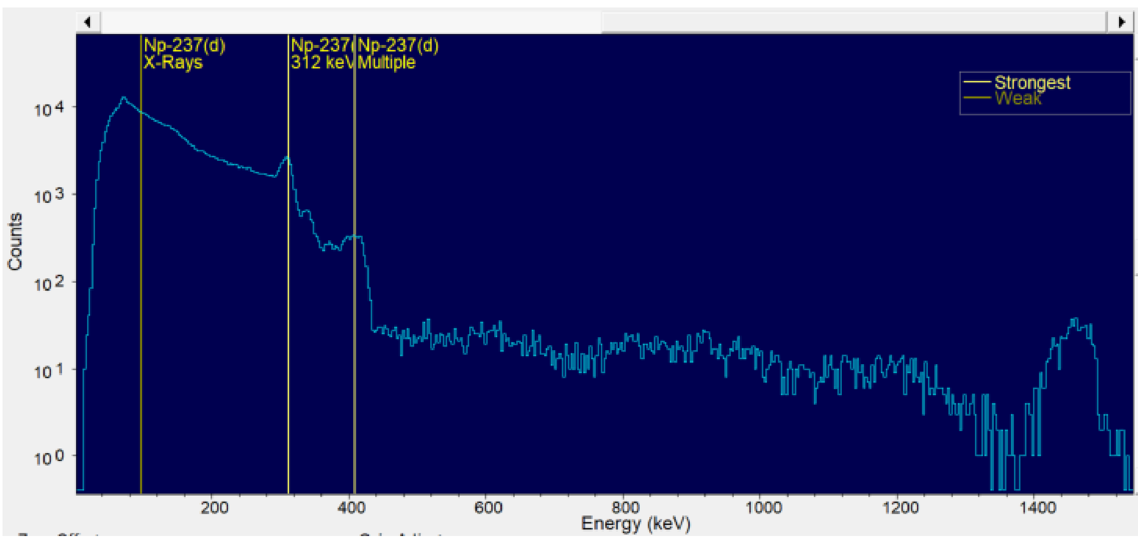

Figure 2. SRM spectrum of ^{237}Np item. The small bump in the x-ray region comes from lead shielding used to shield the measurement from the ID R400 internal ^{137}Cs check source. Additional features beginning to appear and the peaks have smaller FWHMs. The SRM identified ^{237}Np.

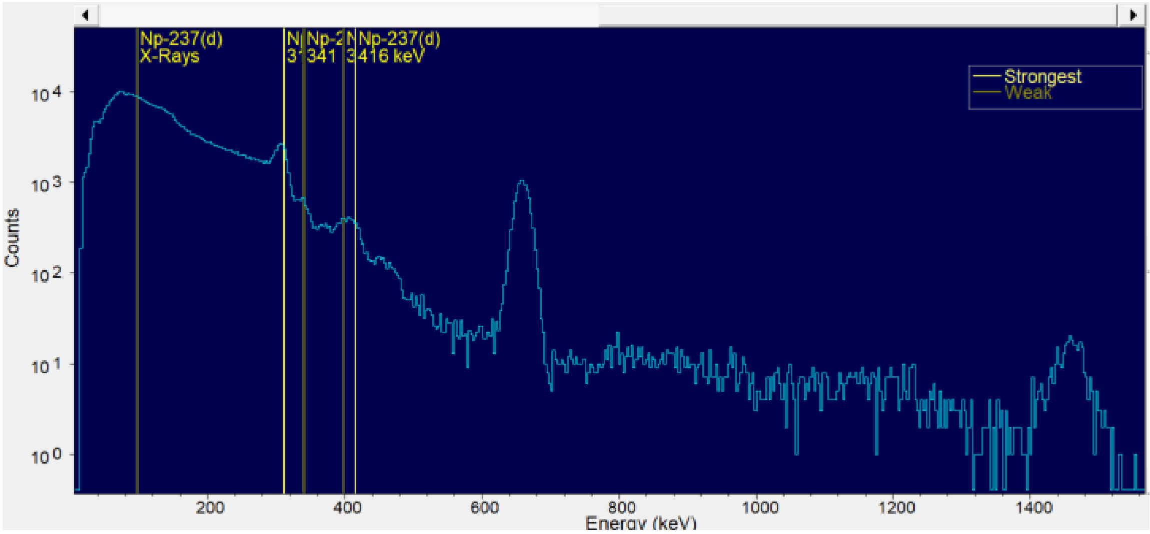

Figure 3. ID R400 spectrum of ^{237}Np item. There is a small bump in the x-ray region from the LaBr internal x-rays. There is also a ^{137}Cs peak from the internal check source. This detector has similar resolution to the SRM detector. The ID R400 identified ^{237}Np and ^{67}Ga. ^{67}Ga was not present but is similar to ^{237}Np regarding spectral data.

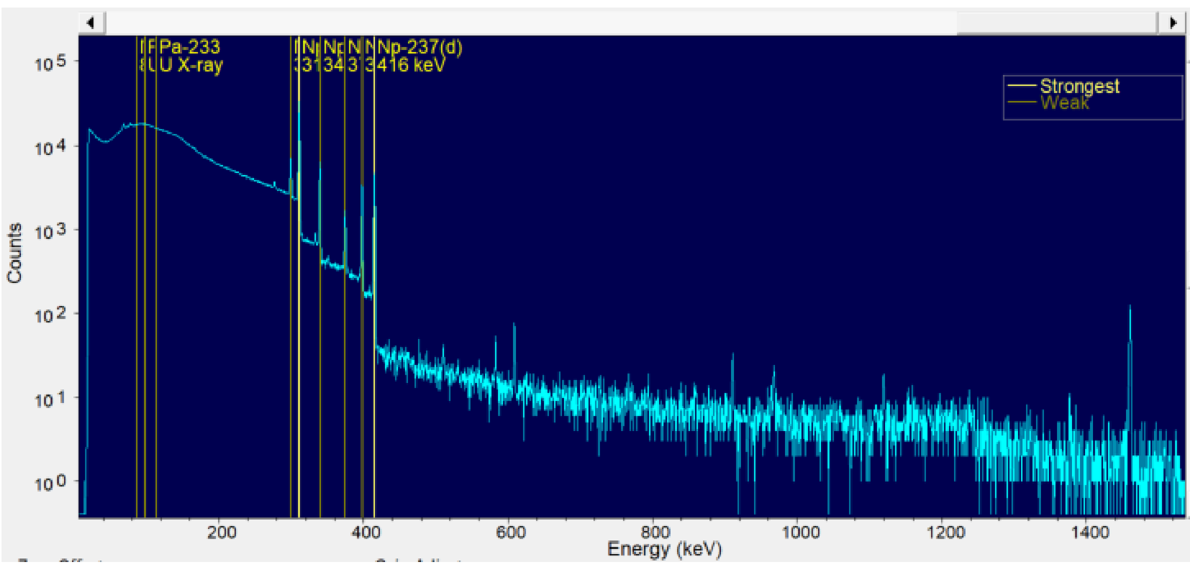

Figure 4. HPGe spectrum of ^{237}Np item for comparison.

Figures 5-8 show spectra of a plutonium oxide item of kg quantity.

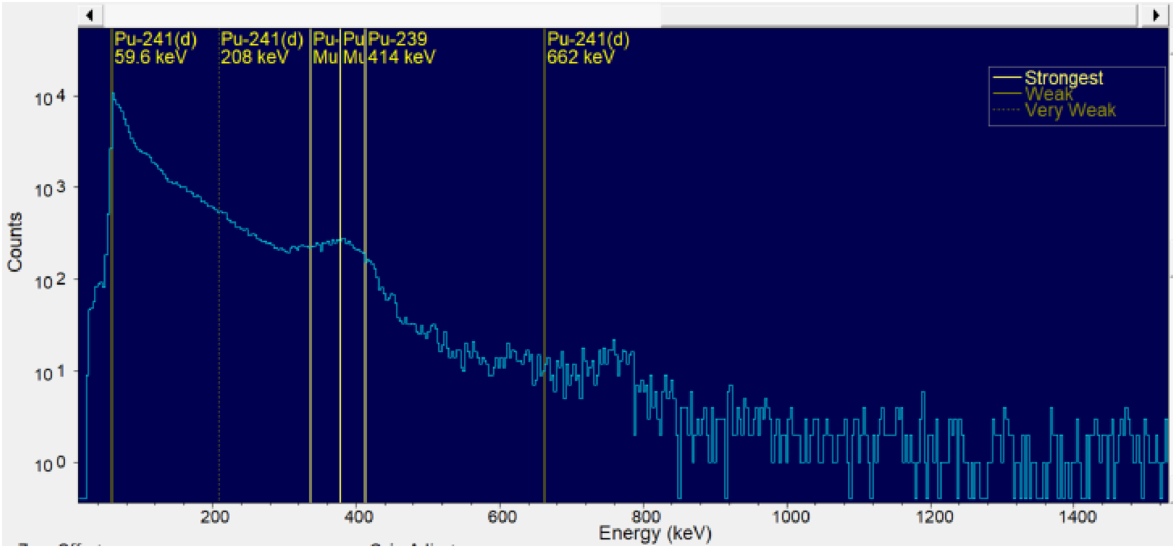

Figure 5. Polimaster spectrum of plutonium oxide item. The Polimaster did not identify plutonium at all. It identified ^{67}Ga, ^{113}Sn, ^{67}Gd, ^{103}Pb, none of which were present. The plutonium peaks in the 400 keV region are present but present as one hump due to the low resolution of the detector.

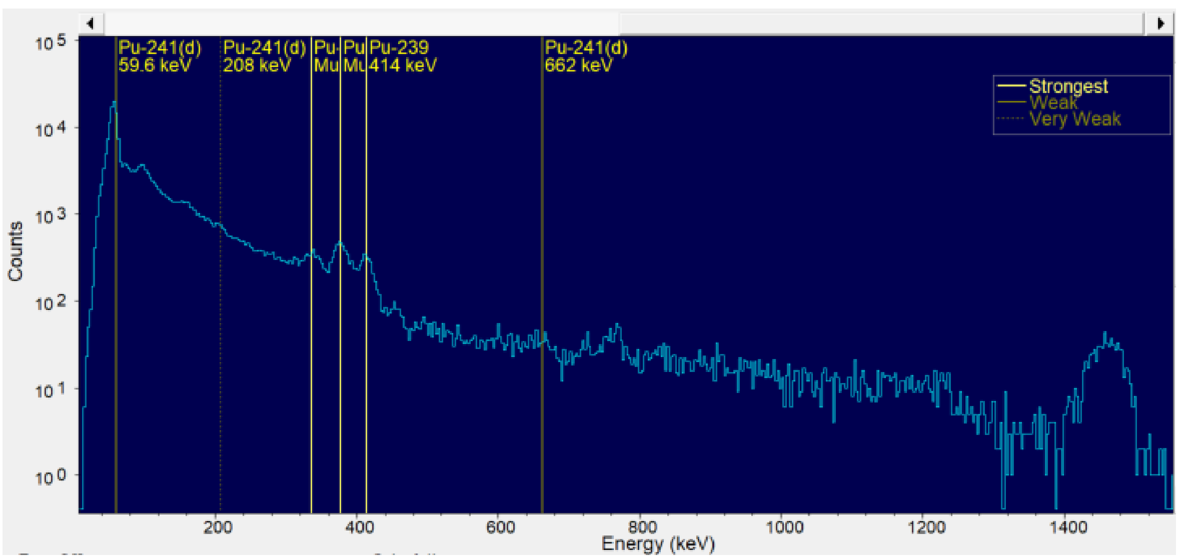

Figure 6. SRM spectrum of plutonium oxide item. It reported no identification. The peaks in the 400 keV region for plutonium are starting to be discernable with the increased resolution.

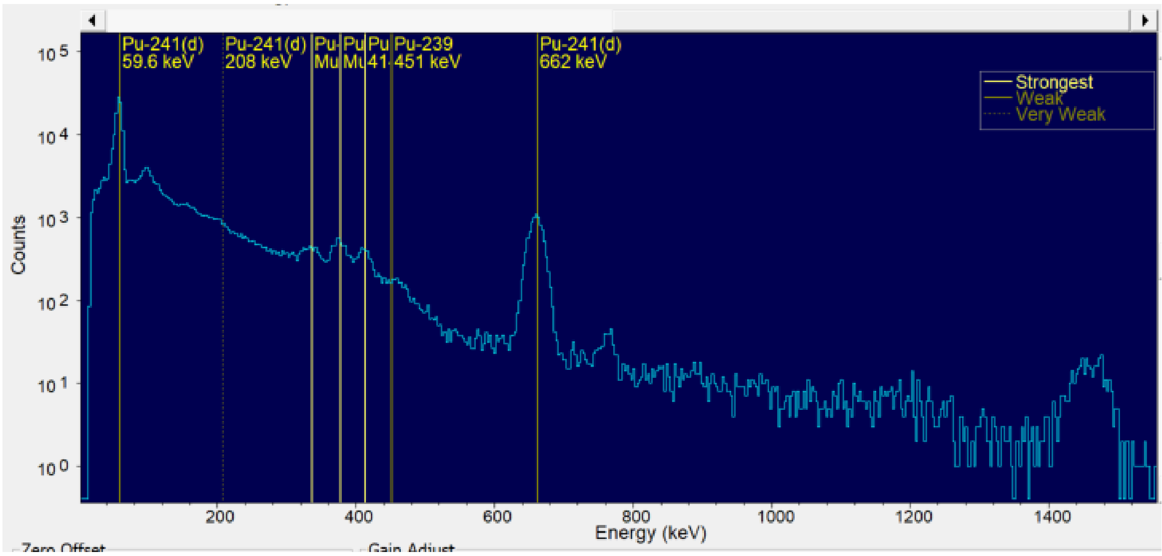

Figure 7. ID R400 spectrum of plutonium oxide item. It identified ^{241}Am and WGPu. It also alarmed for neutrons. These were all present in the configuration. The 662 keV peak presents much larger in this spectrum due to the internal ^{137}Cs check source of the detector, not the ^{241}Pu(daughter) peak from the plutonium item.

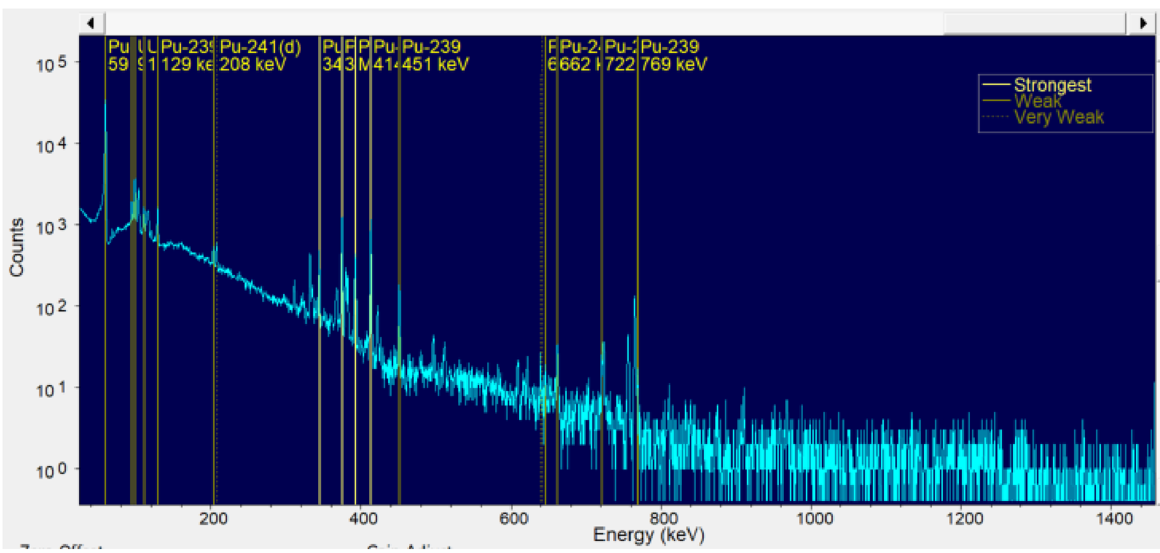

Figure 8. MicroDetective spectrum of plutonium oxide item for comparison.

Figures 9-12 show spectra of a HEU item of kg quantity.

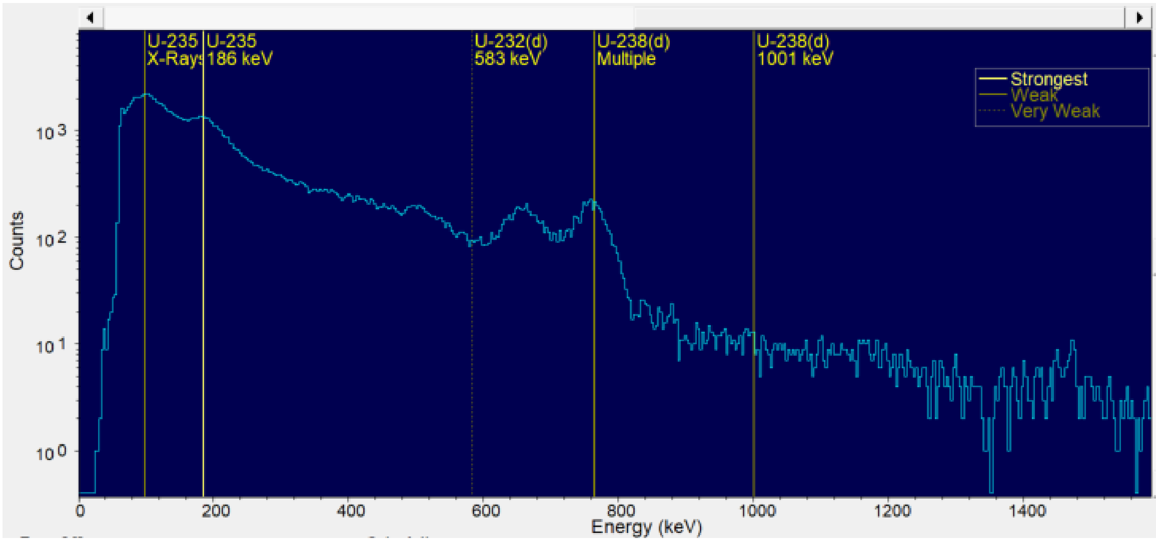

Figure 9. Polimaster spectrum of HEU item. The Polimaster identified Uranium 235, but listed uncertain. It also identified ^{137}Cs, ^{40}K, and ^{194}Ir. The ^{137}Cs and ^{40}K would be present in the measurement environment from the ID R400 internal check source and background. The 662 keV ^{137}Cs peak is visible in the spectrum. ^{194}Ir was not present.

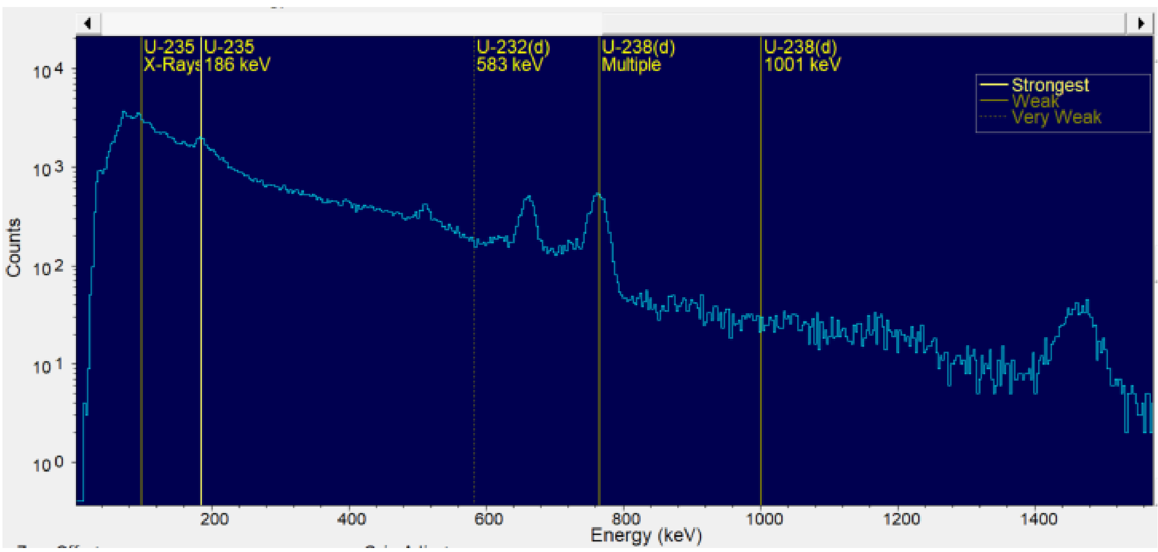

Figure 10. SRM spectrum of HEU item. The SRM did not provide an identification. However, the expected peaks for HEU are present and better defined in the spectrum than the Polimaster spectrum.

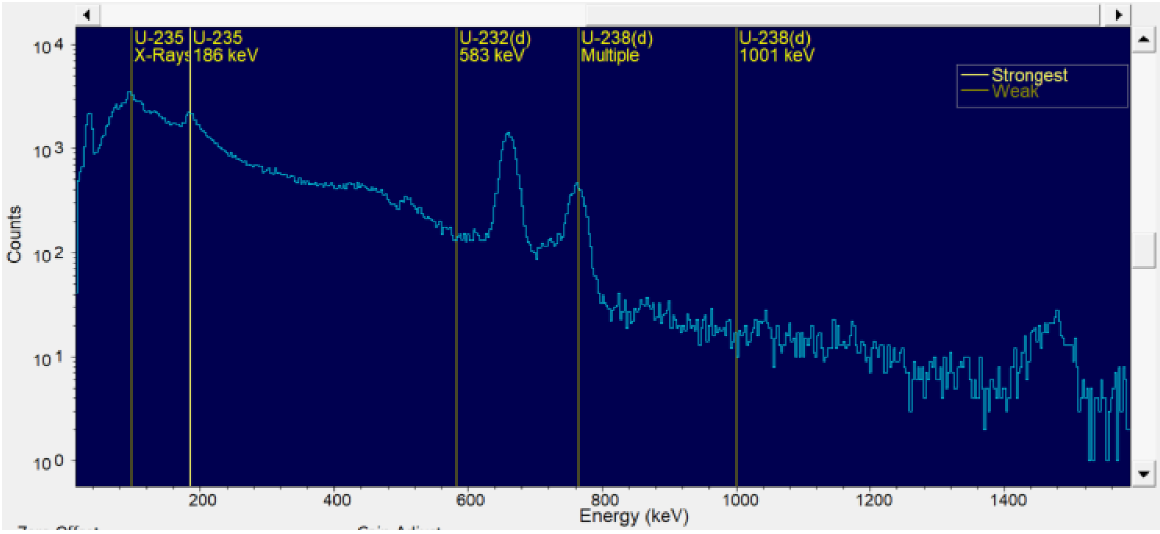

Figure 11. ID R400 spectrum of HEU item. The ID R400 identified ^{110m}Ag, which was not present. It did not identify uranium. However, the expected peaks for HEU are present and better defined in the spectrum than the Polimaster spectrum.

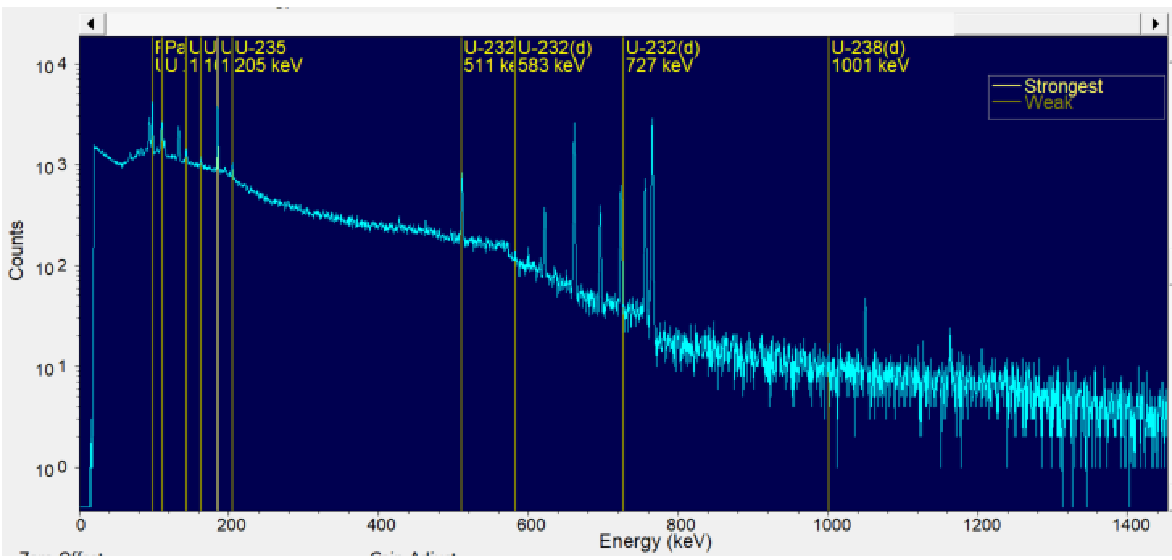

Figure 12. MicroDetective spectrum of HEU item for comparison.

Figures 13-15 show spectra of a ^{233}U item of gram quantity. Due to the small quantity and container shielding, some of the lower branch ratio and low energy peaks are not visible in the spectra. This would contribute some to the mis-identifications or no identifications for the detectors. The SRM spectrum is omitted due to a battery error that interrupted the measurement and caused issues with the spectrum. The SRM identified ^{241}Am, which was not present during the measurement.

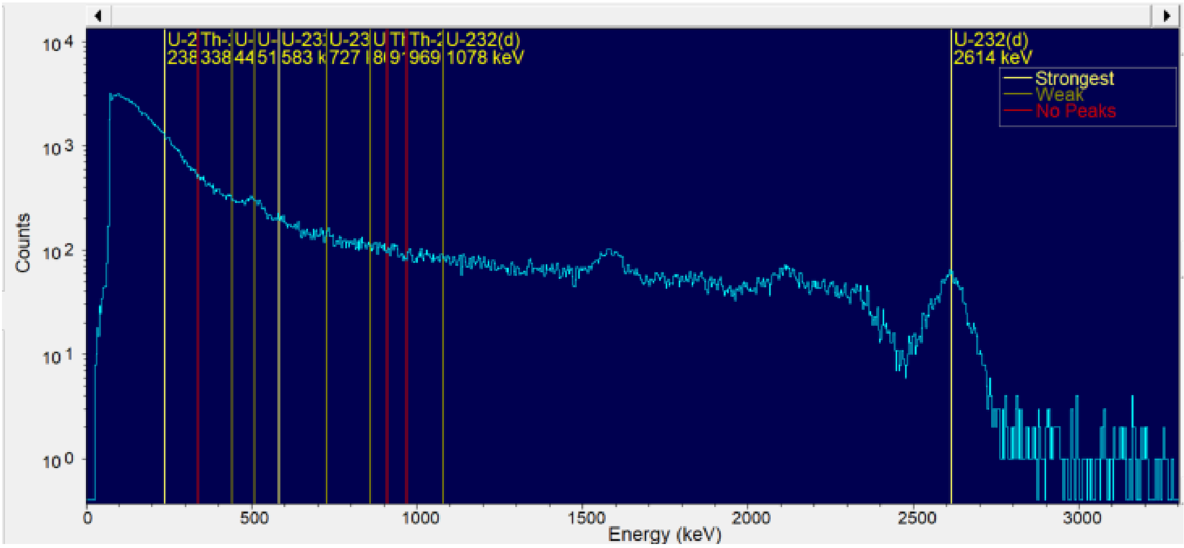

Figure 13. Polimaster spectrum of ^{233}U item. With a label of certain, the Polimaster identified ^{232}Th. With a label of uncertain, it identified ^{228}Th and ^{103}Pb. With a label of very uncertain, it identified ^{22}Na and ^{44}Ti, neither of which were present. ^{232}Th and ^{228}Th are common identifications on ^{233}U items as they are part of the ^{232}U decay chain.

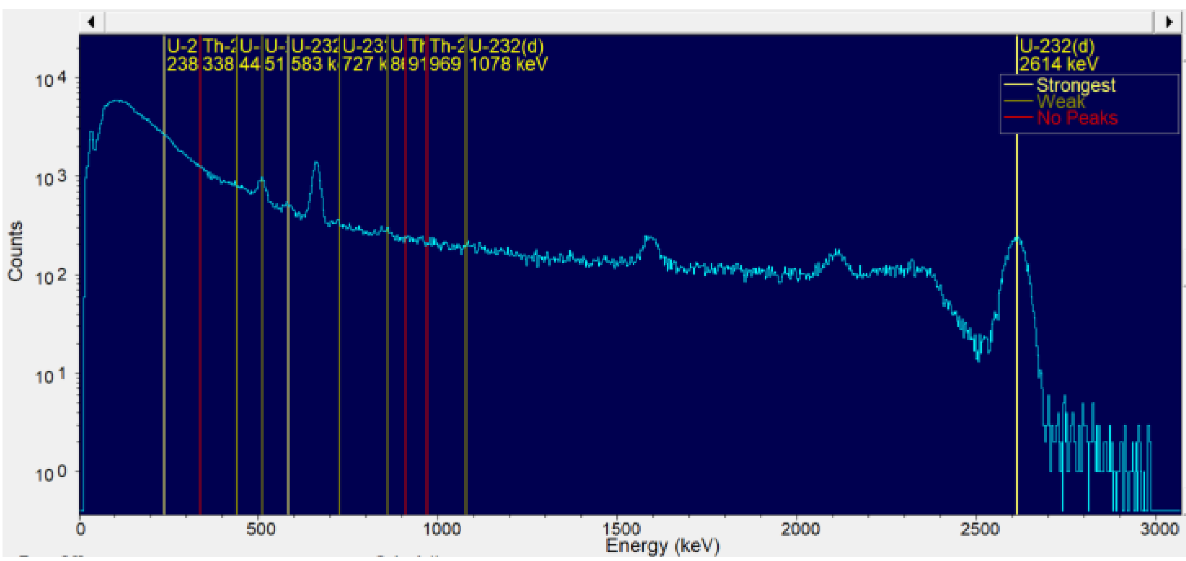

Figure 14. ID R400 spectrum of ^{233}U item. The ID R400 identified annihilation radiation. 511 keV is a gamma line of a ^{232}U daughter, so is seen in ^{233}U spectra.

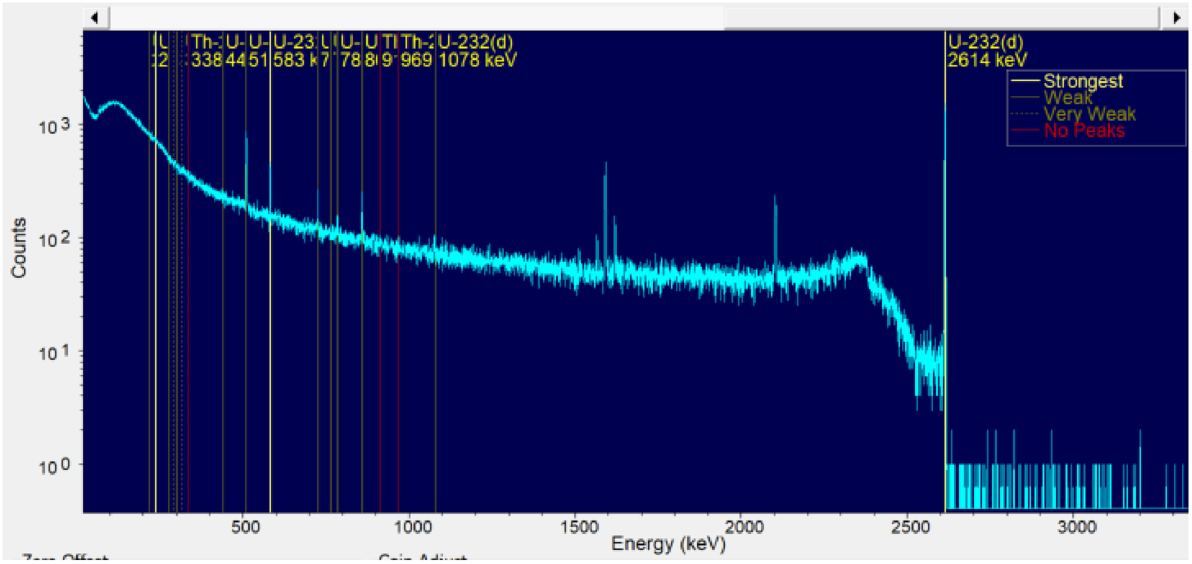

Figure 15. MicroDetective spectrum of ^{233}U item for comparison.

Conclusion:

The Polimaster, as a lower resolution detector cannot discern peaks that the SRM or ID R400 can use for identification. The identification algorithm in the Polimaster causes it to display as many guesses as possible, which can be confusing for the operator. It also tends to rank incorrect identifications above the actual isotope present. The SRM and ID R400 will simply not give an identification if the uncertainty is too high or the software cannot discern between peaks. This approach provides less confusion for a field team. Although the algorithms did not identify the isotopes, in most cases spectral analysis by a gamma spectroscopist would be able to provide a cursory identification.

Neutron Testing

Measurements were taken with several neutron sources with varying levels of moderation to compare the Polimaster and ID R400 ^{3}He neutron detectors. In all measurements, the Polimaster had higher readings for neutrons, indicating a higher detector efficiency. This is expected due to the larger volume of ^{3}He present in the Polimaster. Additionally, the Polimaster demonstrated a greater sensitivity to moderation. The increase in count rate using a moderator, such as the human body or polyethelene, was much more pronounced in the Polimaster than the ID R400 (approximately 100 cps versus 20 cps for the same moderator).

Figure 16. Neutron measurement comparison with a bare ^{252}Cf source. The Polimaster shows a count rate of 35.8 CPS, and the ID R400 shows a count rate of 7.9 CPS. Left: ID R400. Right: Polimaster.

Figure 17. Neutron measurement comparison with a ^{252}Cf source in a 2” ID/4” OD sphere of mock high explosives. The Polimaster shows a count rate of 52.7 CPS, and the ID R400 shows a count rate of 12.7 CPS. Left: ID R400. Right: Polimaster.

Figure 18. Neutron measurement comparison with a ^{252}Cf source in a 4” ID/6” OD sphere of mock high explosives. The Polimaster shows a count rate of 95.1 CPS, and the ID R400 shows a count rate of 27.2 CPS. Left: ID R400. Right: Polimaster.

Figure 19. Neutron measurement comparison with a ^{252}Cf source in a 6” ID/8” OD sphere of mock high explosives. The Polimaster shows a count rate of 121 CPS, and the ID R400 shows a count rate of 30.3 CPS. Left: ID R400. Right: Polimaster.

Alpha/Beta Testing

Measurements were taken with 4 separate alpha check sources for comparison with the FH-40 HP-380A alpha probe. Beta measurements were taken with a Strontium-90 check source. The Polimaster registered half as many counts per minute as the FH-40. Overall, the process to do alpha and beta measurements cannot be considered field expedient. To do independent alpha or beta measurements, the user must follow a 5-6 step process that involves changing filters and/or putting the detector in a plastic bag.

Figure 20. Polimaster alpha filter.

The detector has an alpha/beta/gamma search mode; however, the efficiency is quite low in this mode when compared to the FH-40 for alpha measurements. The Polimaster alpha mode drops in efficiency dramatically as the activity increases.

Figures 21-24 compare the FH-40 HP-380A probe, Polimaster in alpha/beta/gamma search mode, and Polimaster in alpha mode only for each of the alpha check sources.

Figure 21. Comparison measurements of 1,440 DPM ^{239}Pu source. Left: FH-40 with HP-380A probe. Middle: Polimaster in alpha/beta/gamma search mode. Right: Polimaster in alpha mode.

The calculated absolute efficiencies are shown below.

FH-40: $\frac{230\ CPM}{1{,}440\ DPM} * 100 = 15.97\%$

Polimaster in alpha/beta/gamma search mode: $\frac{1.48\ CPS * \frac{60\ Sec}{1\ Min}}{1{,}440\ DPM} * 100 = 6.17\%$

Polimaster in alpha mode: $Detector\ Surface\ Area: \pi r^2 = \pi * \left(\frac{3.49\ cm}{2}\right)^2 = 9.57\ cm^2$

$$\frac{88\frac{CPM}{cm^2}*9.57\ cm^2}{1{,}440\ DPM}*100 = 58.5\%$$

Figure 22. Comparison measurements of 13,500 DPM ^{239}Pu source. Left: FH-40 with HP-380A probe. Middle: Polimaster in alpha/beta/gamma search mode. Right: Polimaster in alpha mode.

The calculated absolute efficiencies are shown below.

FH-40: $\frac{CPM}{13{,}500\ DPM}*100 = 17.8\ \%$

Polimaster in alpha/beta/gamma search mode: $\frac{20\ CPS*\frac{60\ Sec}{1\ Min}}{13{,}500\ DPM}*100 = 8.9\ \%$

Polimaster in alpha mode: $Detector\ Surface\ Area: \pi r^2 = \pi * \left(\frac{3.49\ cm}{2}\right)^2 = 9.57\ cm^2$

$$\frac{951\frac{CPM}{cm^2}*9.57\ cm^2}{13{,}500\ DPM}*100 = 67.4\ \%$$

Figure 23. Comparison measurements of 117,000 DPM ^{239}Pu source. Left: FH-40 with HP-380A probe. Middle: Polimaster in alpha/beta/gamma search mode. Right: Polimaster in alpha mode.

The calculated absolute efficiencies are shown below.

FH-40: $\frac{CPM}{117{,}000\ DPM} * 100 = \ \%$

Polimaster in alpha/beta/gamma search mode: $\frac{147\ CPS * \frac{60\ Sec}{1\ Min}}{117{,}000\ DPM} * 100 = 7.5\ \%$

Polimaster in alpha mode: $Detector\ Surface\ Area\colon \pi r^2 = \pi * \left(\frac{3.49\ cm}{2}\right)^2 = 9.57\ cm^2$

$$\frac{9123\ \frac{CPM}{cm^2} * 9.57\ cm^2}{117{,}000\ DPM} * 100 = 74.6\ \%$$

Figure 24. Comparison measurements of 1,360,000 DPM ^{239}Pu source. Left: FH-40 with HP-380A probe. Middle: Polimaster in alpha/beta/gamma search mode. Right: Polimaster in alpha mode.

The calculated absolute efficiencies are shown below.

FH-40: $\frac{233{,}000\ CPM}{1{,}360{,}000\ DPM} * 100 = 17.1\ \%$

Polimaster in alpha/beta/gamma search mode: $\frac{1831\ CPS * \frac{60\ Sec}{1\ Min}}{1{,}360{,}000\ DPM} * 100 = 8.1\ \%$

Polimaster in alpha mode: $Detector\ Surface\ Area\colon \pi r^2 = \pi * \left(\frac{3.49\ cm}{2}\right)^2 = 9.57\ cm^2$

$$\frac{6382\ \frac{CPM}{cm^2} * 9.57\ cm^2}{1{,}360{,}000\ DPM} * 100 = 4.5\ \%$$